9-1992

Morphological and agronomic variability in Cuphea viscosissima Jacq

W. W. Roath
United States Department of Agriculture

Mark P. Widrlechner
United States Department of Agriculture, isumw@iastate.edu

R. Kleiman
United States Department of Agriculture

Morphological and agronomic variability in Cuphea viscosissima Jacq

Abstract

Cuphea viscosissima Jacq. has been proposed as a possible domestic source of medium-chain triglycerides, particularly capric acid (10:0), a 10-carbon saturated fatty acid. Domestication of this species is dependent upon obtaining variability for the constraining characters necessary to make this wild species into an economic crop. This paper reports the variability found among 40 accessions of this species recently collected from the central US. plus three other accessions, all part of the *Cuphea* germplasm collection at the North Central Regional Plant Introduction Station. Morphological variability is very limited. Significant differences were found in plant mass, plant height, postharvest seed dormancy, seed shatter, 100-seed weight, seed yield, oil content, and the amounts of caprylic (8:0) and capric (10:0) acid. The degree of natural variation in seed size, seed yield and in oil percent and fatty acids could be exploited to produce improved cultivars.

Keywords

Cuphea, Fatty acid, Germplasm, New crop

Disciplines

Agricultural Science | Agriculture | Agronomy and Crop Sciences | Horticulture | Plant Breeding and Genetics | Plant Sciences

Comments

This article is from *Industrial Crops and Products* 1 (1992): 5–10, doi:10.1016/0926-6690(92)90038-W.

Industrial Crops and Products, 1 (1992) 5–10

INDCRO 00001

Morphological and agronomic variability in *Cuphea viscosissima* Jacq.

W.W. Roath[1], M.P. Widrlechner[1] and R. Kleiman[2]

[1] *USDA — Agricultural Research Service, Plant Introduction Station, Iowa State University, Ames, IA 50011, USA and*
[2] *USDA — Agricultural Research Service, National Center for Agricultural Utilization Research, Peoria, IL 61604, USA*

(Received 25 March 1991; accepted 20 February 1992)

Abstract

Roath, W.W., Widrlechner, M.P. and Kleiman., R. 1992. Morphological and agronomic variability in *Cuphea viscosissima* Jacq. Industr. Crops Products 1: 5–10.

Cuphea viscosissima Jacq. has been proposed as a possible domestic source of medium-chain triglycerides, particularly capric acid (10 : 0), a 10-carbon saturated fatty acid. Domestication of this species is dependent upon obtaining variability for the constraining characters necessary to make this wild species into an economic crop. This paper reports the variability found among 40 accessions of this species recently collected from the central US. plus three other accessions, all part of the *Cuphea* germplasm collection at the North Central Regional Plant Introduction Station. Morphological variability is very limited. Significant differences were found in plant mass, plant height, postharvest seed dormancy, seed shatter, 100-seed weight, seed yield, oil content, and the amounts of caprylic (8 : 0) and capric (10 : 0) acid. The degree of natural variation in seed size, seed yield and in oil percent and fatty acids could be exploited to produce improved cultivars.

Cuphea; Fatty acid; Germ plasm; New crop;

Introduction

Seed oils of *Cuphea* species have diverse fatty acid compositions (Earle et al., 1960; Miller et al., 1964), with most species possessing relatively high percentages of medium-chain fatty acids (MCFAs) especially caprylic, capric and lauric acids (Graham, 1989; Hirsinger, 1985; Hirsinger and Knowles, 1984). Lauric acid (12 : 0) is used primarily in the manufacture of soaps and detergents. Triglycerides of caprylic (8 : 0) and capric (10 : 0) acids are used in specialized clinical diets to alleviate certain digestive disorders caused by the metabolism of the long-chain fatty acids (Babayan, 1981). Approximately 500 000 metric tons of coconut and palm kernel oils are imported into the United States each year and these oils are the primary source of MCFAs. The search for domestic alternatives led to the present efforts to develop select *Cuphea* species as a source of MCFAs for industrial and food use (Gillis, 1988; Graham, 1989; Hirsinger, 1985; Hirsinger and Knowles, 1984; Thompson, 1984).

One species currently being investigated for its potential value as new oilseed source is *Cuphea viscosissima* Jacq. More than 65% of the total

Correspondence: W.W. Roath, USDA - Agricultural Research Service, Plant Introduction Station, Iowa State University, Ames, IA 50011, USA.

fatty acid composition of its seed oil is capric acid (10:0), a fatty acid rarely found in this proportion elsewhere among herbaceous flowering plants (Graham, 1989; Hirsinger and Knowles, 1984; Knapp et al., 1991). This species is native to the east-central United States (Graham, 1988) and is well adapted to the temperate climate. Nearly all other *Cuphea* species are neotropical. Constraints to domestication of this species include prolonged postharvest seed dormancy, indeterminate flowering habit, seed shatter and poor harvestable seed yield (Knapp, 1990; Knapp and Tagliani, 1989; Thompson, 1984). Identification of variability for the constraining characteristics is necessary to be able to overcome these constraints.

A very limited amount of germplasm (three accessions at the North Central Regional Plant Introduction Station, (NCRPIS) at Ames, IA) of this species existed in gene banks prior to 1987. This lack of genetic diversity severely limited the ability to initiate an effective domestication program. A plant collection trip to remedy this situation was conducted by Roath and Widrlechner in September, 1987. This paper reports the results of the evaluation of the material collected plus the three additional accessions of *C. viscosissima* at the NCRPIS.

Materials and Methods

Plant materials

Forty accessions were collected in south-central US (Fig. 1). Herbarium vouchers for the collection are deposited at Kent State University, Kent, OH. Thirty-nine accessions had viable seed and were included in the survey with three other accessions that were in the NCRPIS collection. These three accessions were collected in Virginia, Missouri, and West Virginia.

Because the degree of postharvest seed dormancy was unknown, the testa of each seed was removed, the excised seed grown on water agar plates, and seedlings transplanted to the greenhouse in 1987–88 (Roath and Widrlechner, 1988). Subsequently, approximately 2-month-old seedlings were transplanted into the field at Ames, IA, on 26 May, 1988. Up to 60 seedlings of each accession were planted in three-row plots. The rows were 46 cm apart and 6.1 m long.

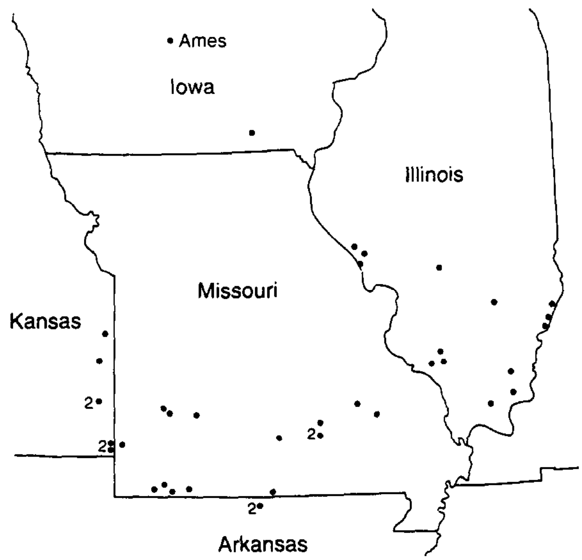

Fig. 1. Collection sites for *Cuphea viscosissima* Jacq., 1987.

In 1989, 20 accessions with the greatest 1988 seed yield were grown in a replicated field trial, following procedures used in 1988. The data were analysed as a randomized complete block.

Evaluation data: morphology

Growth habit was described as prostrate, semi-erect or erect. The presence and location of glandular trichomes was determined. The relative amount of resin secreted by the trichomes was estimated on a 1–4 scale: 1 = none; 2 = light; 3 = moderate; and 4 = heavy. Plant height was recorded in centimeters after measurement of four plants per accession at random. Plant mass was measured by weighing individual dried above-ground plant material collected after harvest. These data were taken from the 1988 plantings. An analysis of variance, completely randomized design, was used to analyse mean differences in plant height and mass.

Stem color was characterized by the predominant color of the upper stems, near the flowers. Photographs of a random plant of each accession were taken by using Kodak Ektachrome 200 film. These photographs were viewed under fluorescent light and compared with the Munsell color charts (Munsell, 1976) to determine the color.

Floral tube color was determined by the Munsell system by using the procedure just described. The predominant color of a side view of the floral tube in full bloom was used to determine this character.

Petal color was determined by using the same procedure described by viewing the petals from a full-face view of flowers in full bloom. The number of upper and lower petals was counted.

Agronomic data
Harvest was accomplished after the first killing frost on 6 October, 1988, and 23 September, 1989. The plants were either placed into mesh bags and artificially dried, or rolled onto large isolation screens and allowed to dry in the greenhouse. Seed was shaken from the plants, cleaned with a desk-top clipper-type cleaner, and/or in a column blower.

Seed from the 38 accessions increased in 1988 were germinated 6 months after harvest to check for degree of postharvest dormancy. Two 100-seed replications for each accession were placed in clear plastic germination boxes on moistened blotter paper for 21 days. The boxes were placed under continuous light at room temperature of approximately 24°C.

The gram weight of 100 seeds per accession was determined, and yield in kg/ha of each accession in the replicated trial was determined. Shatter was assessed by placing 30 x 90 cm trays between rows of individual plots of the replicated trial when the first mature seed was observed. Seeds were collected from the trays weekly until harvest and total kg/ha of seed collected was determined.

Oil determinations on whole-seed samples were made by using a low resolution pulsed NMR, (Bruker Minispec PC 120, 18 mm absolute probehead). A calibration curve was prepared using weighed samples of oil suspended on tissue material. The seed was then measured against the calibration curve to determine the amount of oil present. The weight of the seed was corrected for moisture and the percent oil determined on a dry basis. Fatty acids of the seed were determined by gas-liquid chromatography after transesterfication to their methyl esters (Wolf et al., 1983). Content of single fatty acids was computed as a percentage of the total fatty acids.

Correlations were performed between the following pairs: plant height and mass, seed yield and 100-seed weight, seed yield and percent oil, and percent 8:0 and 10:0, 8:0 and 12:0, and 10:0 and 12:0 fatty acids.

TABLE 1

Plant height, mass and germination of *Cuphea viscosissima* accessions

PI no.	Plant height (cm)	Plant mass (g)	Germination (%)[a]
534726	36.0	90.3	—
534730	32.0	91.2	—
534734	23.3	88.5	8.0
534735	24.0	87.0	6.0
534736	32.5	99.8	5.0
534737	22.5	52.0	7.5
534738	23.6	159.6	1.0
534739	27.5	115.8	1.5
534740	28.3	115.2	5.5
534741	30.8	151.7	4.0
534742	29.3	91.2	4.5
534743	28.0	107.1	7.5
534744	21.0	84.1	5.0
534745	26.0	118.0	6.5
534746	24.8	105.6	3.5
534747	18.0	49.4	—
534748	16.5	67.5	4.0
534749	23.5	82.2	2.0
534750	26.3	102.0	2.5
534751	26.3	88.7	1.5
534752	32.5	84.7	7.5
534753	32.0	91.0	13.0
534754	31.0	104.0	3.5
534755	31.0	123.1	2.5
534756	30.5	86.4	2.0
534757	23.3	116.0	6.5
534758	31.5	69.1	0.5
534759	30.0	67.0	8.0
534760	39.0	76.9	2.5
534761	35.8	80.9	1.0
534762	27.3	91.0	2.0
534763	30.5	91.3	4.5
534764	29.5	73.5	13.5
534765	31.7	25.4	16.5
534766	35.3	60.9	8.0
534767	28.5	56.1	4.0
534768	30.0	88.1	3.0
534769	26.5	53.6	8.0
534770	27.3	69.9	2.0
534771	30.5	72.3	8.0
534911	38.8	81.0	—
A7897	32.0	59.8	3.5
lsd $P=0.05$	8.3	33.6	NS

[a] Germination of 6-month-old seed.

Results

Morphology
Except for plant height and plant mass (Table 1), little variation exists between or within accessions

for morphological characteristics observed. All plants were semi-erect. Glandular trichomes were present on all stems, and the amount of resin produced was moderate. The mean plant height ranged from 16.5 to 39.0 cm, with a significant variance ($P > 0.01$). The range of means of plant mass was 25–160 g per plant ($P > 0.01$). There was no significant correlation between plant height and plant mass.

Only one accession (PI 534750 from near Mountain Home, AR) differed significantly from the predominant red-purple color of new-growth stems of wild-type plants. The wild-type stem color by the Munsell color notation was red-purple (10RP5/8). The mutant stem color was yellow-green (10YG8.5/4 by the Munsell color notation).

Floral tube color for all accessions was green (2.5G5/8 by the Munsell color notation). Petal color for all accessions was red-purple. PI 534750 varied from the wild type in hue, value (darkness), and chroma (grayness). The wild type petal color was a darker, more vivid red-purple (10RP4/10), whereas the variant petal color was a paler, lighter red-purple (5RP8/6 by the Munsell color notation). Other flower characteristics were the same for all accessions.

Agronomic data

Prolonged postharvest dormancy has been observed in many *Cuphea* species (Thompson, 1984). Some nonsignificant variation in seed germination was recorded in 38 of these accessions (Table 1). The range in mean germination of 6-month-old seed was 0.5–16.5%.

The values for 100-seed weight, seed yield, shatter, percent oil and percent fatty acids for 8:0, 10:0 and 12:0 are shown in Table 2. Means

TABLE 2

Seed characteristics of *Cuphea viscosissima* accessions

PI no.	swt[a]	Yield (kg/ha)	Shatter (kg/ha)	Oil (%)[b]	8:0 (%)[c]	10:0 (%)[c]	12:0 (%)[c]
534726	0.190	431	59.9	24.9	13.6	68.3	3.1
534730	0.210	357	62.4	25.9	13.9	64.4	2.5
534734	0.210	353	56.9	25.0	14.0	66.7	3.3
534739	0.205	497	85.4	26.7	14.3	68.6	3.0
534740	0.245	273	62.9	27.6	15.1	66.8	3.4
534741	0.220	461	68.7	27.2	14.5	68.2	3.3
534742	0.210	370	66.3	26.8	14.9	65.5	3.3
534744	0.195	368	54.7	24.7	14.9	66.7	3.4
534745	0.220	408	65.6	27.3	14.9	67.8	3.3
534746	0.265	349	43.5	26.9	14.6	67.8	3.3
534749	0.225	215	20.0	27.1	13.4	66.9	3.9
534751	0.195	286	46.7	27.8	15.0	68.4	3.1
534754	0.200	340	59.1	27.1	14.4	66.7	3.3
534756	0.215	565	33.5	28.1	14.3	66.7	3.3
534757	0.220	458	38.7	27.7	14.2	68.5	3.2
534762	0.205	588	33.8	26.9	15.6	65.6	3.3
534763	0.190	381	52.6	27.1	15.0	68.1	3.1
534766	0.215	352	20.7	28.4	13.9	67.7	3.0
534768	0.210	269	69.3	27.3	14.0	67.7	3.3
534911	0.220	456	53.2	26.1	14.1	65.5	3.2
lsd ($P = 0.05$)	0.066	163[d]	31.1	1.9	0.9	2.2	NS

[a] swt = seed weight of 100 seeds in grams.
[b] Percent oil on an oven-dry basis.
[c] Percent of total fatty acids.
[d] $P = 0.10$.

differed significantly for all these characteristics except lauric acid (12 : 0). Probability levels for the significant mean differences were 5% except for seed yield at 10%. The range of means for 100-seed weight was 0.19–0.265 g/100 seeds, seed yield 215–588 kg/ha, shatter 20.0–85.4 kg/ha, oil 24.9–28.4%, caprylic acid (8 : 0) 13.4–15.6%, capric acid (10 : 0) 64.4–68.5%, and lauric acid (12 : 0) 2.5–3.9%. There are no significant correlations between any of the seed characters measured.

Discussion

Morphology

Cuphea viscosissima is self-pollinated (Hirsinger and Knowles, 1984) and, therefore, would be expected to be less variable than if it were a cross-pollinated species. However, it was surprising to find so little morphological variation among 39 accessions collected from over such a wide range. The sizes of individual plants (i.e., height or mass) were the only characteristics with measurable differences.

Agronomic data

Prolonged postharvest dormancy is a serious constraint to domestication of *Cuphea* because dormancy slows breeding progress. Hirsinger and Knowles (1984) reported a nondormant population of *C. viscosissima*. None of our accessions are significantly nondormant and the degree of nondormancy observed is too low to be readily exploitable (Table 1). *Cuphea viscosissima* crosses readily with the closely related *C. lanceolata* Aiton, producing fully fertile progeny (S. Knapp, personal communication, 1990). Contrary to Hirsinger and Knowles' report (1984), *C. lanceolata* is much less dormant than *C. viscosissima* (Roath, unpublished data) and we have started a backcross program to convert *C. viscosissima* accessions to nondormancy by introducing genes from *C. lanceolata*.

The lack of variability in morphological characters did not carry over into other agronomically important characters. The degree of natural variation in seed size, seed yield and in oil percent and fatty acids could be exploited to produce improved cultivars. Fatty acid composition and oil content reported here substantiate findings by Knapp et al. (1991) at Corvallis, OR, that quantities of MCFAs and percent oil vary in this species. The lack of significant correlation between many of these characters should allow improvement in one without a negative effect on another.

These accessions possess the zygomorphic flower character typical of most *Cuphea* species; thus, the potential exists for considerable seed shatter. This is substantiated by the degree of observed seed loss due to shatter (Table 2). It is not possible to explain the variation in shatter recorded in this trial. It is doubtful that this variation can be exploited to reduce the amount of seed shatter.

Acknowledgments

The authors thank B.J. Morrell, S.M. Beck and B. Phillips for their technical assistance in conducting these trials and gathering the data. Journal Paper No. J-14219 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Project No. 1018. Mention of commercial brand named products does not constitute an endorsement of any product by USDA — Agricultural Research Service or cooperating agencies.

References

Babayan, V.K., 1981. Medium chain length fatty acid esters and their medical and nutritional applications. J. Am. Oil Chemists Soc., 58: 49A–51A.

Earle, F.R., Glass, C.A., Geisinger, C. A., Wolff, I.A. and Jones, Q., 1960. Search for new industrial oils. J. Am. Oil Chemists Soc., 37: 440–447.

Gillis, A., 1988. Update: developing new commercial crops. J. Am. Oil Chemists Soc., 65: 6–20.

Graham, S.A., 1988. Revision of *Cuphea* section Heterodon (Lythraceae). Systematic Botany Monographs. Vol. 20. American Society Plant Taxonomists, Univ. of Michigan, Ann Arbor, MI.

Graham, S.A., 1989. *Cuphea*: a new plant source of medium-chain fatty acids. Crit. Rev. Food Sci. Nutrit., 28: 139–173.

Hirsinger, F., 1985. Agronomic potential and seed composition of *Cuphea*, an annual crop for lauric and capric seed oils. J. Am. Oil Chemists Soc., 62: 78–80.

Hirsinger, F. and Knowles, P.F., 1984. Morphological and agronomic description of selected *Cuphea* germplasm. Econom. Botany, 38: 439–451.

Knapp, S.J., 1990. New temperate industrial oilseed crops. In: J. Janick and J.E. Simon (Eds.). Advances in New Crops. Timber Press, Portland, OR, pp. 203–210.

Knapp, S.J. and Tagliani, L.A., 1989. Genetic variation for seed dormancy in *Cuphea laminuligera* and *Cuphea lanceolata*. Euphytica 47: 65–70.

Knapp, S.J., Tagliani, L.A., and Roath, W.W., 1991. Fatty acid and oil diversity in *Cuphea viscosissima*: a source of medium-chain fatty acids. J. Am. Oil Chemists Soc., 68: 515–517.

Miller, R.W., Earle, F.R., Wolff, I.A. and Jones, Q., 1964. Search for new industrial oils IX. *Cuphea* a versatile source of fatty acids. J. Am. Oil Chemists Soc., 41: 279–280.

Munsell Book of Color. 1976. Macbeth Division of Kallmorgen Corp. Baltimore, MD.

Roath, W.W. and Widrlechner, M.P., 1988. Inducing germination of dormant *Cuphea* seed and the effects of various induction methods on seedling survival. Seed Sci. Technol., 16: 699–703.

Thompson, A.E., 1984. *Cuphea* a potential new crop. Hort Science 19: 353–354.

Wolf, R.B., Graham, S.A. and Kleiman, R., 1983. Fatty acid composition of *Cuphea* seed oils. J. Am. Oil Chemists Soc., 60: 27–28.